AMS-214

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Marketing Research Division

STUDIES OF DDVP FOR CONTROL OF CIGARETTE BEETLES IN TOBACCO WAREHOUSES

By J. N. Tenhet, C. O. Bare, and D. P. Childs, Stored-Tobacco Insects Laboratory, 1/ Richmond, Va.; and W. F. Durham, Communicable Disease Center, 2/ Savannah, Ga.

SUMMARY

Three series of tests were made to explore the usefulness of DDVP in controlling the cigarette beetle in tobacco warehouses. In an exploratory series conducted in semiclosed warehouses, all test insects in the airspaces between hogsheads of tobacco were killed by aerosols applied at the rate of 4.25 grams of DDVP per 1,000 cubic feet; by emulsion sprays applied to the exposed floor and walls and the underside of the roof at a rate of 3.45 grams of DDVP per 1,000 cubic feet; and by a solution sprinkled in the aisles at a rate of 2.1 grams per 1,000 cubic feet. In semiclosed warehouses, the vapors continued to be effective, and insects introduced 24 and 48 hours after treatment were killed within 24 hours. Mortality was low in ventilated warehouses after 24 hours. Deposits on slides showed poor aerosol distribution. Rats exposed in the treated warehouses for 7 days showed no signs of poisoning.

In a second series, in which DDVP aerosols were used, test insects in the free spaces of warehouses were killed when exposed 1 hour to dosages of 1 gram per 1,000 cubic feet or above. Adults exposed for 24 hours 1 week after treatment showed 43 percent mortality. Exposed eggs were not affected by a dosage rate of 4.25 grams, and there was no significant mortality of larvae or adults at various depths in the tobacco.

In the third series, DDVP solutions were sprinkled on the aisles. At 20-hour exposure rates, results were similar to those of the previous series. However, at shorter exposures, mortalities were lower. In warehouses treated at a 10-gram rate, no symptoms of poisoning were evident in rats and monkeys

1/ This is one of the field stations of the Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

2/ U. S. Public Health Service, Department of Health, Education, and Welfare.

Agriculture--Washington November 1957

exposed 7 days or to human volunteers exposed the equivalent of 2 working days. However, a definite effect was noted on the cholinesterase level of monkeys at the 2- and 10-gram dosage rates. Cholinesterase effects on the human volunteers were borderline and of questionable significance. Depression of the cholinesterase rate would have indicated a toxic effect.

INTRODUCTION

The problem of controlling the cigarette beetle in open (ventilated) and semi-closed tobacco warehouses which cannot be fumigated is particularly acute. A new insecticide has been developed which has proved unusually effective against certain insects. This insecticide, O, O dimethyl 2, 2-dichlorovinyl dimethyl phosphate, is known as DDVP (2). 3/ Preliminary laboratory tests by the manufacturer (4) and by a cigarette manufacturer indicate that this material is effective against the cigarette beetle and does not impart an objectionable flavor or aroma to the tobacco. Studies on the mammalian toxicology of DDVP also have been reported (1).

In preliminary tests, at an industrial laboratory, a solution containing 100 parts per million of DDVP was sprayed directly on flue-cured tobacco. Cigarettes were made from this tobacco after 3 weeks, 6 weeks, and 3 months. Tests showed no change in the aroma or smoking quality of the tobacco. Cut cigarette tobacco was exposed for 6 months to an atmosphere saturated with DDVP vapor. Cigarettes made of this tobacco had normal smoking flavor.

During the summer of 1956, 3 series of tests with DDVP were conducted, 2 at Winston-Salem, N. C., and 1 at Charleston, S. C. The tests were designed to explore the usefulness of DDVP in controlling the cigarette beetle. They were carried out in commercial tobacco storage warehouses containing a total of 35 to 40 million dollars' worth of tobacco. The insecticide was applied by entomologists or by trained personnel under the supervision of entomologists.

TECHNIQUES

Warehouses

Three types of warehouses were used: Type A, semiclosed; type B, ventilated; and type C, closed. The type A warehouses were of corrugated iron construction, with wooden floors and composition roofs. These buildings were two stories high. Tests were made only in the second story, because insect infestation is usually higher there. Such storages had no windows or ventilators, but were not tight enough for fumigation because of numerous small cracks where the sheets of corrugated metal overlapped. However, they were tight enough to prevent rapid movement of air through the building.

3/ Underlined figures in parenthesis refer to Literature Cited, page 17.

The type B warehouses were of similar construction to type A, except that there was an open ventilating strip, about 12 inches wide, around all 4 sides of each building, just below the eaves. This ventilating strip permitted a movement of air through the warehouse and prevented any appreciable build-up of DDVP vapors.

Type C warehouses were one story high, of brick and hollow tile construction, with concrete floors and composition roofs. These units were quite tight--sufficiently so for fumigation.

Each floor of the warehouses of types A and B measured 242 x 110 x 16 feet, and contained approximately 425,000 cubic feet. Each storage section had a capacity of 3,100 hogsheads stored on their sides, or 3,400 to 3,500 hogsheads stored on end with the hogsheads racked 3 tiers high. When filled to normal capacity with tobacco, each section had 250,000 to 260,000 cubic feet of free space. Type C warehouses were 160 x 100 x 18 feet and contained 288,000 cubic feet. Each section had a capacity of 1,900 hogsheads, and when filled to normal capacity had approximately 193,000 cubic feet of free space.

In each warehouse of types A and B, there was a single aisle next to the wall on one side about 10 feet wide and extending the length of the building. A single 20-foot-wide aisle extended across the width of each type C warehouse, about one-third the length of the building from one end.

Test Insects

Cigarette beetles were placed in various locations in each warehouse, at heights of 0 to 14 feet above floor level. Screen-wire cages containing 25 adults each and an indeterminate number of eggs were exposed at these locations in the free air space. Test spikes, containing 25 adults or larvae in each cell, were driven into hogsheads so that a cell was exposed at depths of 1, 3, and 5 inches, and, in some instances, 7 and 9 inches.

The test insects were insectary-reared, of uniform age and culture, and were believed to be as resistant to all insecticides as any natural beetle infestation. Adult beetles had emerged within 24 to 48 hours prior to their use. Eggs were approximately 24 to 48 hours old at the start of each test. Larvae were 2 to 3 weeks old and approximately three-fourths grown. Eggs of the cigarette beetle are fragile and cannot readily be counted or handled. Short sections of midrib of flue-cured tobacco were split lengthwise, and the beetles were allowed to oviposit in these sections of stem. The number of eggs per stem could not be determined without injuring some of the eggs, so the number of eggs varied in each test.

Mortality of test insects was recorded 24 to 72 hours after their removal from the warehouse. All moribund beetles unable to crawl or fly from a sheet of paper 8 x 10 inches were arbitrarily considered dead, as such

beetles never recovered. Incubation of eggs was recorded after 10 to 14 days. Mortality of larvae was recorded 3 to 5 days after the exposure period.

Tests Conducted

Three series of tests were made under tobacco warehouse conditions. The first series, conducted in July at Winston-Salem, N. C., was exploratory. Five warehouses were included, 3 type A (semiclosed), and 2 type B (ventilated). The DDVP was dispersed in three different ways--as a thermal-generated aerosol; as an emulsion spray on the exposed floor, walls, and underside of the roof; and as a solution sprinkled on the floor of the aisle only.

In the second series, conducted in early October at Winston-Salem, the DDVP was dispersed as a thermal-generated aerosol. Three warehouses were included, all type A (semiclosed).

In the third series, conducted in late October at Charleston, S. C., the DDVP was dispersed as a solution sprinkled on the floor of the aisle only. Three warehouses were included, all type C (closed).

Test insects were exposed in the free air space in all series, and some were inserted into the hogsheads of tobacco in the last two series. White rats were exposed in the first series; rats, monkeys, and humans were exposed in the third series. Air samples were taken in the third series and analyzed to determine the concentration of DDVP vapor in the air.

Glass microscope slides were exposed at various locations in warehouses treated with aerosols to indicate distribution of the aerosol.

EXPLORATORY TESTS

Procedure

In this series, thermal-generated aerosols were applied to 1 type A (semiclosed) and 1 type B (ventilated) warehouse. An emulsion spray was applied to the exposed floor, walls, and underside of the roof in 1 type B warehouse. A solution of DDVP was sprinkled on the aisle only of 2 type A warehouses. The warehouse temperatures ranged from 74° to 80° F. Relative humidity was about 70 percent.

The aerosols were produced in a commercial thermal aerosol generator adjusted to produce 97 to 98 percent of the particles with diameters of 3 microns or less. The generator was operated from a point outside the building. The aerosol was introduced into each warehouse at one point (the second

story in each instance) through a length of 4-inch flexible duct which in turn discharged into an 18-inch duct. The aerosol formulation consisted of DDVP dissolved in 5 or 10 gallons of light hydrocarbon oil. A dosage rate of 4.25 grams of DDVP per 1,000 cubic feet was applied to the type A warehouse and a rate of 8.5 grams per 1,000 cubic feet to the type B warehouse. Twelve coated glass microscope slides were placed in each warehouse at locations varying from 2 to 96 feet from the aisles and at heights varying from 0 to 14 feet above the floor. After application of the aerosol, these slides were examined under a microscope and the percentage coverage and range of particle sizes recorded.

The emulsion spray was prepared from a concentrate containing 50 percent of DDVP, 30 percent of tetrachloroethylene, and 20 percent of an emulsifier, diluted in water to 1 percent DDVP. Forty gallons were applied to the exposed floor, walls, and the underside of the roof in 1 type B (ventilated) warehouse, which was the equivalent of 3.45 grams per 1,000 cubic feet of total warehouse space.

The solution consisted of DDVP dissolved in carbon tetrachloride. Three gallons were sprinkled in the aisles of 2 type A (semiclosed) warehouses. Concentrations were 2.1 grams per 1,000 cubic feet in 1 warehouse and 4.25 grams per 1,000 cubic feet in the other.

Sets of 12 cages of adult cigarette beetles were placed in the free air spaces of each warehouse. Six were at floor level and 6 on top of the third tier of hogsheads. They were arranged in a horizontal pattern, with 3 cages about equidistant near the aisle, and 3 near the back wall. The cages were placed in the warehouses before and at intervals after application of the DDVP, and were exposed for 24 or 48 hours, as shown in table 1.

One cage containing 2 male and 3 female white rats of the "Charles River" strain was placed in each warehouse during or immediately after applications of the DDVP, and left undisturbed for 7 days.

Results

The insect mortality results are given in table 1. All test insects were killed in warehouses of both types A and B at all application rates tested, when exposed during the first 24 hours after DDVP had been applied. All test insects exposed during the second or third 24 hours were killed in the type A (semiclosed) warehouses with application rates of 4.25 grams per 1,000 cubic feet and above. Mortality was very low in type B (ventilated) warehouses, under these same conditions. One group of insects exposed for 24 hours, 7 days after application of 4.25 grams per 1,000 cubic feet, had a mortality of 85 percent in a type A warehouse.

Table 1.--Mortality of adult cigarette beetles in the exploratory series of tests following exposure in the free air space of type A and B warehouses that had been treated with DDVP in various manners

Method of application and type of warehouse	Amount of DDVP per 1,000 cubic feet	Exposure period		Mortality
		Started after treatment	Length	
	Grams	Hours	Hours	Percent
Aerosol				
Type A (semiclosed) warehouse	4.25	0	24	100
		24	24	100
		24	48	100
		48	24	100
		72	24	99
		168	24	85
Type B (ventilated) warehouse	8.5	0	24	100
		24	24	25
		24	48	42
		48	24	13
		72	24	2
Spray on floors, walls, and roof				
Type B (ventilated) warehouse	3.45	0	24	100
		24	24	5
		24	48	22
		48	24	2
		72	24	6
Sprinkled in aisles				
Type A (semiclosed) warehouse	2.1	1	24	100
		24	24	99+
		72	24	98
	4.25	1	24	100
		24	24	100
		72	24	100
Controls	-	0	24	1

Distribution of aerosols, as indicated by the deposits on the glass slides, was poor. The heaviest deposit on the slides was nearest the point of introduction, and no deposit occurred in the most distant areas. It was visually observed that the aerosol failed to reach the far ends of the warehouses.

There was no indication of organophosphorus poisoning of any of the exposed rats. No lowering of the cholinesterase level in the blood of the rats was found 3 days after the end of their exposure in the warehouses.

TESTS WITH DDVP APPLIED AS AN AEROSOL

Procedure

In this series of tests the DDVP was applied as an aerosol in three type A (semiclosed) warehouses. A constant amount of solution of 53 ml. per 1,000 cubic feet of total warehouse space was applied in each warehouse. The concentration of DDVP was varied to give dosage rates of 1, 2.1, and 4.25 grams per 1,000 cubic feet. The warehouse temperatures averaged about 85°F.

Sets of 30 cages of beetles were placed on top of the tobacco hogsheads at various levels and locations throughout each warehouse. Each cage contained 25 adult beetles and a 1-inch section of midrib bearing eggs. Cages were placed 16 hours after aerosols were applied. Lots of cages were removed after exposure periods of 4, 12, 18, and 24 hours. An additional set of 6 cages was placed in each warehouse 7 days after the application, and exposed for 24 hours.

Before the application, test spikes were inserted in selected hogsheads so that samples of adults were placed 1, 3, and 5 inches deep, and samples of larvae 1, 3, 5, 7, and 9 inches deep. One spike of each stage was removed after exposures of 24, 48, and 72 hours.

Results

The insect mortality results are given in table 2. All adult beetles were killed when exposed in the free air spaces for 4 hours or more, 16 hours after application, at dosages of 1 gram per 1,000 cubic feet or above. Adults exposed for 24 hours, 1 week (168 hours) after application, at a dosage rate of 1 gram, showed 43 percent mortality; at a rate of 2.1 grams, 65 percent mortality; and at a rate of 4.25 grams, 83 percent mortality. However, eggs hatched normally when exposed in the free air space to all application rates tried and with exposures up to 24 hours. There was no significant mortality of either adults or larvae at any depth in the tobacco hogsheads.

Table 2.--Mortality of test insects in type A (semiclosed) tobacco warehouses treated with DDVP aerosols

Amount of DDVP applied	Exposure period		Mortality--exposed in free air space		Mortality--inserted in tobacco hogsheads	
	Started after treatment	Length	Adults	Eggs	Adults	Larvae
	Hours	Hours	Percent	Percent	Percent	Percent
1 gram per 1,000 cubic feet	0	24			0	1
		48			3	7
		72			5	6
	16	4	100	67		
		12	100	73		
		18	100	62		
		24	100	61		
	168	24	43			
2.1 grams per 1,000 cubic feet	0	24			0	8
		48			0	9
		72			0	4
	16	4	100	73		
		12	100	75		
		18	100	64		
		24	100	78		
	168	24	65			
4.25 grams per 1,000 cubic feet	0	24			1	6
		48			1	5
		72			1	8
	16	4	100	48		
		12	100	79		
		18	100	77		
		24	100	82		
	168	24	83			
Controls	--	--	0	78	1	5

TESTS WITH DDVP APPLIED TO THE FLOOR OF AISLES ONLY

Procedure

In the third series of tests, DDVP was dissolved in tetrachloroethylene and sprinkled on the floor of the aisles in 3 type C (closed) warehouses. DDVP in 3 gallons of solvent was applied in each of the 3 warehouses in amounts that resulted in application rates of 1, 2, and 10 grams per 1,000 cubic feet of total warehouse space, respectively. The warehouse temperatures averaged 72°F. A wind of 10 to 15 miles per hour persisted for the first 8 hours of the tests.

Two and one-half hours after application of the DDVP, sets of 8 cages, each containing 25 adult beetles and a 1-inch section of midrib bearing eggs, were placed in warehouses treated with 1- and 2-gram rates. Sets were removed after 1, 2, and 4 hours' exposure. Other sets were placed in the warehouses 22 hours after treatment and exposed 4 hours, and others were placed 28 hours after treatment and exposed 20 hours.

Before application of DDVP at the 10-gram rate, 16 test spikes were inserted in hogsheads, 8 placing larvae at depths of 1, 3, and 5 inches, and 8 placing adults at the same depths. One-half of each lot was exposed 24 hours, the other half 48 hours.

Six white rats of the Sherman strain were placed in each warehouse before treatment and left undisturbed for 7 days. Two mature rhesus monkeys were placed in warehouses which had received applications of 2 and 10 grams per 1,000 cubic feet. Four human volunteers were exposed to DDVP vapors for the equivalent of 2 working days. On the day after application, 2 of the men spent 8 hours in the warehouse treated at the 1-gram rate, and 2 spent 8 hours in the warehouse treated at the 2-gram rate. The next day all 4 men entered the warehouse treated at the 10-gram rate. One stayed 4 hours and 3 stayed 7 hours. Blood samples were taken from test animals and the volunteers before and during the exposure periods.

Air samples were collected at various intervals from the treated warehouses for analysis of DDVP content. Samples were collected on Celite absorption columns and were analyzed by the total phosphorus method (3).

Results

The insect mortality results are given in table 3. The increased lengths of exposure gave progressive increases in mortality of adult insects exposed in the free air spaces, but only one of the dosage exposure combinations caused mortality of all those insects. The 10-gram application rate did not inhibit egg incubation. There was no significant mortality of either adults or larvae at any depth in the tobacco hogsheads with exposures up to 48 hours and an application rate of 10 grams.

Table 3.--Mortality of test insects in type C (closed) tobacco warehouses treated with DDVP solution sprinkled in the aisles

Amount of DDVP applied	Exposure period		Mortality--exposed in free air space		Mortality--inserted in tobacco hogsheads	
	Started after treatment	Length	Adults	Eggs	Adults	Larvae
	Hours	Hours	Percent	Percent	Percent	Percent
1 gram per 1,000 cubic feet . . .	2½	1	44	1		
		2	59	1		
		4	79	3		
	22	4	82	1		
	28	20	99+	-		
2 grams per 1,000 cubic feet . . .	0	24		4		
		48		3		
	2½	1	63	1		
		2	83	3		
		4	93	3		
	22	4	75	2		
	28	20	100	-		
10 grams per 1,000 cubic feet . . .	0	24			15	16
		48			10	32
Controls	--	--	1	3	8	9

No symptoms of DDVP poisoning were observed in any of the rats, monkeys, or men during or after exposure in the treated warehouses.

As shown in table 4, cholinesterase activity levels for the rats in the warehouses receiving dosages of 1 or 2 grams of DDVP per 1,000 cubic feet were not depressed from the control values. However, both male and female rats exposed to the 10-gram dosage did show, on the average, some decrease of plasma and erythrocyte enzyme action. Figure 1 illustrates the blood cholinesterase levels for both plasma and erythrocytes during the period of their exposure. The monkeys exposed to the 10-gram dosage showed a more severe depletion than did those exposed to the 2-gram dosage. The preexposure and postexposure plasma and erythrocyte cholinesterase levels of the human volunteers are shown in table 5. All 4 subjects had a decreased plasma enzyme activity after their first exposure. After the second exposure, 1 person had a further small decrease in plasma cholinesterase, whereas the other 3 actually had increased levels. In the erythrocyte enzyme level, little change was noted after the first exposure, whereas 3 of the 4 subjects had lower levels after the second exposure. These observations were not unexpected in view of the known tendency toward rapid recovery of DDVP-inactivated plasma cholinesterase and the slower recovery rate of the erythrocyte enzyme. None of the volunteers at any time showed any severe diminution of cholinesterase level, all the variations being almost or completely within normal limits of variability for population values.

A rapid screening test (Limeros-Ranta bromthymol blue method) for the determination of approximate cholinesterase levels of the human volunteers was carried out at intervals during the tests. None of the individuals, including the 4 experimental subjects and 2 controls, showed any decrease in cholinesterase level detectable by this procedure (that is, there was less than 25 percent decrease).

Analysis of air samples from the treated warehouses is given in table 6. The air in the warehouses treated at dosages of 1 and 2 grams per 1,000 cubic feet reached maximum levels of 19.7 and 48.3 milligrams per 1,000 cubic feet, (0.7 and 1.7 mmg. per liter) respectively. These values decreased to undetectable levels within 48 hours of treatment. In each instance, the maximum concentration of DDVP in air actually observed was only about 2 percent of the theoretical maximum. The warehouse treated with a 10-gram dosage showed about the same DDVP concentration 24 hours after treatment as the one receiving the 2-gram dosage. However, the toxicant concentration remained at a high level much longer, still being 11.2 milligrams per 1,000 cubic feet after 7 days.

DISCUSSION

It is apparent that the vapor phase of DDVP was responsible for most of the insecticidal effectiveness demonstrated in these tests. For an insect to be affected it was not necessary for it to come in actual contact with particles of spray or with the deposit on a sprayed surface. In studies of the

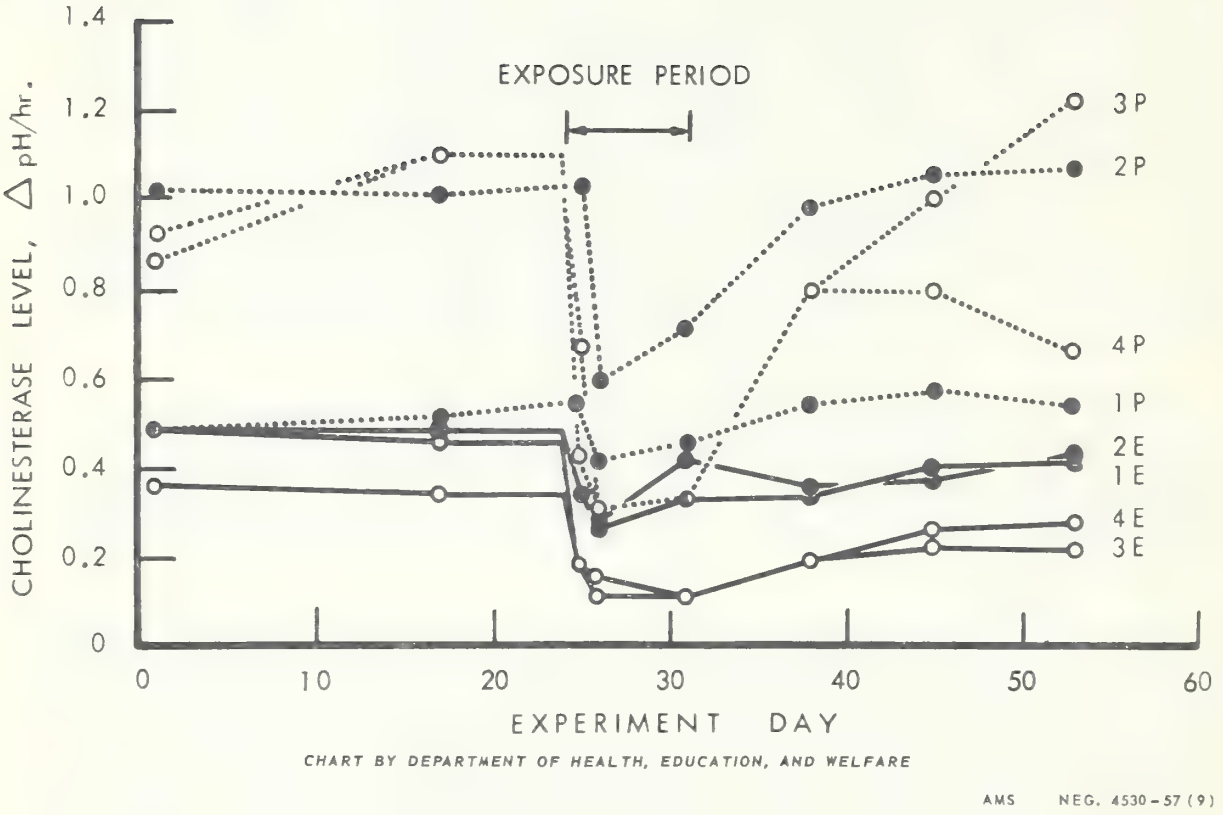

Figure 1.--Plasma (P) and erythrocyte (E) cholinesterase values of monkeys exposed for 7 days in warehouses treated with DDVP at 2 (lines 1 and 2) and 10 (lines 3 and 4) grams per 1,000 cubic feet.

Table 4.--Plasma and erythrocyte cholinesterase levels of rats exposed for varying periods of time in tobacco warehouses treated with indicated amounts of DDVP

Amount of DDVP and length of exposure	Cholinesterase level (Δp H/hr.)			
	Males		Females	
	Plasma	Erythrocytes	Plasma	Erythrocytes
1 gram per 1,000 cubic feet				
1 day	0.25	0.14	0.28	0.12
2 days	.35	.14	.31	.18
7 days	.24	.10	.33	.22
Mean	.28	.13	.31	.17
2 grams per 1,000 cubic feet				
1 day	.21	.15	.25	.13
2 days	.22	.15	.24	.14
7 days	.26	.22	.37	.20
Mean	.23	.17	.29	.19
10 grams per 1,000 cubic feet				
1 day	.19	.11	.18	.15
2 days	.22	.13	.21	.15
7 days	.20	.15	.27	.16
Mean	.20	.13	.22	.15
Controls	.32	.17	.23	.19

Table 5.--Plasma and erythrocyte cholinesterase values of human volunteers exposed to DDVP vapors in tobacco warehouse

Subject	Cholinesterase value (Δp H/hr.)					
	Plasma			Erythrocytes		
	Pre-exposure	After first exposure	After second exposure	Pre-exposure	After first exposure	After second exposure
D. B.	0.79	0.73 1/	0.76 10a/	0.77	0.72 1/	0.46 10a/
J. E.	1.00	.78 1/	.89 10a/	.61	.69 1/	.56 10a/
J. G.	.98	.80 2/	.93 10a/	.69	.61 2/	.43 10a/
R. T.	.60	.51 2/	.46 10b/	.51	.54 2/	.78 10b/

1/ 8-hour exposure in 1 gram/1,000 cu. ft. warehouse.
2/ 8-hour exposure in 2 grams/1,000 cu. ft. warehouse.
10a/ 7-hour exposure in 10 grams/1,000 cu. ft. warehouse.
10b/ 4-hour exposure in 10 grams/1,000 cu. ft. warehouse.

Table 6.--Content of DDVP in air in tobacco warehouses at various times after treatment with the insecticide at different dosages

Interval after treatment	DDVP content (micrograms per liter) at--		
	1 gram per 1,000 cu. ft.	2 grams per 1,000 cu. ft.	10 grams per 1,000 cu. ft.
2-3 hours	0.7, 0.5	1.6, 1.7	--
24 hours	.2, .2	.7, .9	0.9
48 hours	< .3	< .4	1.4
3 days	--	--	--
7 days	<.04, <.04	<.04, <.04	.4, .4

distribution of DDVP aerosols in the exploratory series, the aerosols were not observable in some parts of each warehouse, and only a small part of each warehouse showed deposits on the slides. Yet complete kills of test insects occurred at all points in the air spaces in the buildings. Furthermore, in type A (semiclosed) warehouses, the vapors apparently permeated the entire air space and continued to kill all beetles for 3 days. This reaction was further demonstrated where the treatment with DDVP consisted of sprinkling a solution of the material on the floor of the aisle. In all test warehouses, the vapors quickly permeated the air space and killed insects 100 feet from the points of application. It is noteworthy that this action was not found to occur in ventilated buildings. Where there was air movement through the warehouse, apparently it was impossible to build up lethal concentration of vapor.

This vapor movement is a matter of considerable importance. One of the greatest limitations in the use of aerosols and space sprays to control the cigarette beetle has been the difficulty of obtaining adequate distribution. Tobacco warehouses are usually very large and so designed and so filled with tobacco that satisfactory distribution of spray is frequently unobtainable. The use of DDVP might solve this problem.

Another useful property of this insecticide is its short residual action. A deposit of DDVP in a tobacco warehouse will continue to liberate vapors for several days. However, it is sufficiently volatile that, at practical dosages, all or most of the material vanishes in about 2 weeks, as shown by the air concentration values. This gives some prolongation of insecticidal action, but seems to eliminate all fears of permanent insecticidal residues contaminating the tobacco.

The tests concerned with mammalian toxicity indicate that treatment of tobacco warehouses with DDVP at the rate of 10 grams per 1,000 cubic feet might constitute a hazard to workers. This judgment is based upon observed effects on cholinesterase levels of rats, monkeys, and humans, and upon air concentration values. The results of the tests at levels of 1 and 2 grams per 1,000 cubic feet were less clear-cut. However, indications are that at least the latter concentration might be too high for safety, since an effect from the dosage was seen on the cholinesterase level of exposed monkeys. Still, it should be noted that these monkeys were not only exposed continuously for 7 days but also were exposed to the high concentrations of vapor occurring during the application of the insecticide and immediately thereafter. In contrast, laborers working in treated warehouses would never be exposed to the high initial concentration of vapors and they would be exposed for only 8 hours, or less, in any one day, except under unusual circumstances.

LITERATURE CITED

(1) Durham, W. F., Garner, T. B., McCauley, R. H., Sedlak, V. A., Mattson, A. M., and Hayes, W. J., Jr. 1957. Studies of the toxicity of O, O-dimethyl, 2, 2-dichlorovinyl phosphate (DDVP). AMA Arch. Industrial Health 15: 340.

(2) Mattson, A. M., Spillane, J. T., and Pearce, G. W. 1955. Dimethyl 2, 2-dichlorovinyl phosphate (DDVP), an organic phosphorus compound highly toxic to insects. Jour. Agr. Food Chem. 3: 319.

(3) Nakamura, G. R. 1955. Microdetermination of phosphorus. Anal. Chem. 23: 1830.

(4) Tracy, R. L., Gentile, J., and Wenneis, J. M. 1956. Concentration of DDVP insecticide for the cigarette beetle. Paper presented at fourth annual meeting of Entomological Society of America, New York, N. Y.

PREVIOUS ISSUES OF THIS SERIES RELATED TO
STORED-PRODUCT INSECTS

AMS-4. Fumigation of dry beans and cowpeas on the packaging line. January 1955.

AMS-5. Procedure for the fumigation of dry beans and cowpeas on the packaging line. January 1955.

AMS-49. Timing of sprays to control the cigarette beetle. May 1955.

AMS-58. An insect preventive program for peanut warehouses. June 1955.

AMS-64. Protecting stored seed from insect attack. (Revision of former Bureau of Entomology and Plant Quarantine publication E-677, issued December 1945.) July 1955.

AMS-73. Effect of varying the volatilization of methyl bromide by combinations with various solvents on its distribution in bulk grain fumigation. December 1955.

AMS-101. Studies on separation of weevil-infested from noninfested wheat by flotation. March 1956.

AMS-131. Enclosures for fumigating stored raisins. July 1956.

AMS-150. Experiments on distributing methyl bromide in bulk grain with aeration system. January 1957.

AMS-151. Experiments on distributing liquid fumigants in bulk grain with aeration system. January 1957.

AMS-152. Experiments on distributing HCN in bulk grain with aeration system. January 1957.